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# Fungicidal Control of South American Leaf Blight of Hevea Rubbertrees

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A SOUND AND LASTING SOLUTION to the problem of a continuous and economic rubber supply for the American nations lies in the establishment of a rubber-growing industry in tropical America. In past years, the greatest single obstacle to the establishment of such an industry has been South American leaf blight, the major disease of the Para rubbertree (*Hevea brasiliensis* (H. B. K.) Muell. Arg.). The causative agent, a fungus, *Dothidella ulei* P. Henn., has long occurred on the wild hevea rubbertrees throughout the Amazon Basin. In their jungle habitat, these scattered trees do not often suffer severely from attacks of leaf blight, but when trees are planted row upon row in nurseries or fields, the opportunities for disease development and spread are greatly increased. Most of the early plantation rubber enterprises in tropical America were ruined by ravages of leaf blight.

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[1] Grateful acknowledgments are made to the Goodyear Rubber Plantations Co., for making available to the hevea seedling nurseries in which the initial spraying and dusting tests were conducted; to the following members of the staff of Rubber Plant Investigations of this Bureau: T. J. Grant and R. D. Rands, for advice and assistance on the preparation of the manuscript; and Arturo Lizano, for assistance in carrying out the field tests.

Leaf blight now occurs throughout the Amazon Basin and locally as far north as Costa Rica, and it is likely that the wind-blown spores of this fungus will eventually be carried to all hevea plantings on the American Continents and nearby coastal islands. Hence, leaf blight control should be given due consideration in planting programs in areas not yet invaded by the disease. Adequate insurance will be provided by the use of disease-resistant clones for all field plantings. After leaf blight invades a new area, additional rootstocks to expand field plantings can be obtained by spraying the seedling nurseries.

## THE PRESENT RUBBER-PLANTING PROGRAM

The cooperative intergovernmental program of rubber investigations that was begun in 1940 has as its goal the establishment of a permanent and self-sustaining rubber-growing industry in tropical America. The broad cooperative plan of this program and a review of early progress were described in a report by Brandes (*3*).[2] Problems and procedures connected with hevea rubber culture in Latin America were discussed by Rands in a recent publication (*10*). Other recent articles (*2*, *4*, *5*, *6*, *8*, *11*) by representatives of cooperating government agencies and commercial firms engaged in rubber-plant improvement and rubber culture in the American Tropics have described the progress made on projects under way in several countries. The program as a whole involves the planting of bud-grafted, superior-yielding, and blight-resistant strains of the tree, but until these have been multiplied sufficiently, plantings may be made with high-yielding, susceptible Eastern clones provided with resistant tops. The use either of susceptible seedlings as rootstocks or of Eastern clones to be top-budded requires control of leaf blight in infested areas. This circular reports the results of experiments that have demonstrated the feasibility of controlling this disease by spraying.

## EARLY ATTEMPTS TO PROTECT HEVEA BY SPRAYING

Beginning early in the present century, several thousand acres of hevea rubbertrees were planted in British and Dutch Guiana and on the nearby island of Trinidad (*9*). Leaf blight spread to these plantings from wild hevea trees growing in the nearby jungle and soon became a serious problem. The recommendations made for disease control in the effort to save the threatened rubber-growing industry were concerned largely with sanitary measures, especially the removal of badly diseased portions of the plants, but they included also some suggestions for disease control by spraying.

Kuyper (*7*) in 1911 and Bancroft (*1*) in 1916 recommended sanitary measures for the control of leaf blight and both suggested the possibility of spraying with bordeaux mixture. Stahel (*13*) made an extensive study of leaf blight in Dutch Guiana and in 1917 reported that young hevea leaves sprayed with bordeaux mixture sometimes made almost healthy growth but at other times curled up and dropped. During this period no satisfactory method of disease control was demonstrated, and the otherwise promising young rubber-growing industry of the Guianas was abandoned. In more recent years a few attempts to control leaf blight in nurseries by spraying and dusting were considered unsuccessful.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 20.

## EXPERIMENTS IN PANAMA AND COSTA RICA

Experiments have now demonstrated that leaf blight can be satisfactorily controlled by spraying with copper and sulfur fungicides. Spraying is recommended as a temporary protective measure to enable nursery seedlings and high-yielding disease-susceptible clones to grow to a suitable size for budding.

The spraying of seedlings in nurseries until the plants reach budding size, at approximately 1 year of age, has been demonstrated to be effective in leaf blight control in large nurseries in several localities. More recent tests have shown the feasibility of spraying high-yielding susceptible clones, growing either in the nursery or in the field, until they are large enough to be top-budded with disease-resistant selections at a height of 6 or 7 feet. Top budding affords a means of combining a high-yielding stem, or tapping panel, with a disease-resistant top. This practice will become unnecessary after clones combining both high yield and disease resistance have been multiplied and distributed.

Spraying tests initiated at All Weather Estate, Panama, late in 1940 were extended to Cairo and Turrialba, Costa Rica, during the period 1941–43. The tests both at All Weather Estate and at Cairo were carried out in cooperation with the Goodyear Rubber Plantations Co., and in large nurseries spraying increased the number of buddable plants fivefold. At the Cooperative Rubber Plant Field Station of the United States Department of Agriculture, at Turrialba, a locality offering very favorable conditions for leaf blight development, sprayed plots after 16 months yielded more than 85 percent buddable seedlings, compared with less than 1 percent on similar unsprayed plots.

Bordeaux mixture, lime-sulfur solution, a number of "insoluble" copper and wettable sulfur fungicides, and several organic fungicidal compounds have been tested as sprays for nursery seedlings. The "insoluble" copper fungicides have proved very satisfactory, and the wettable sulfurs, though somewhat less effective, have given excellent disease control when applied frequently enough. In preliminary tests, Fermate (ferric-dimethyl-dithio-carbamate) has given very promising results as a substitute for copper and sulfur sprays. Bordeaux mixture and liquid lime-sulfur, especially the former, gave excellent disease control but injured the young foliage under some conditions. The effectiveness of both copper and sulfur sprays has been notably increased by the addition of spreaders and stickers to the spray mixture. In small-scale tests, dusting was somewhat less effective than spraying.

In sprayed nurseries a few hundred yards from plantings of badly diseased hevea, disease control was much more easily obtained than in nurseries growing adjacent to large groups of diseased plants.

Procedures recommended for leaf blight control include effective methods of laying out and spraying of hevea nurseries.

## IMPORTANT CONSIDERATIONS IN THE CONTROL OF LEAF BLIGHT

High-yielding hevea clones, like high-quality varieties of many tree fruits, are propagated by grafting their buds on 1- or 2-year-old seedling plants. Thus, the resultant budded stump consists of a seedling rootstock with a grafted bud patch a few inches above the ground. From this bud patch grows the above-ground part of the tree.

Budwood of superior clones can be multiplied a hundredfold each year, but the seed gardens that are now being planted with highly resistant selections to provide future sources of resistant seeds will not come into production until they are several years old; therefore, seedlings to be used as rootstocks are a limiting factor in the extension of hevea plantings in tropical America. Fortunately, seed-producing hevea plantings already exist in most tropical American countries, and the wild trees of the Amazon Basin produce large quantities of seeds. Most of these seed sources, however, produce only blight-susceptible seedlings, and these may not develop into satisfactory rootstocks unless protected against this disease.

Leaf blight attacks the young tissue of all above-ground parts of susceptible plants. Losses of more than 90 percent of the seedlings in unprotected nurseries are not uncommon. Thus spraying, which in blight-infested areas should be begun soon after the nursery seedlings emerge from the soil and be continued at the required intervals until they have been successfully budded, at the approximate age of 1 year, offers a means of utilizing disease-susceptible seeds from the presently available sources.

The practicability of spraying seedling nurseries is emphasized by the fact that, according to the nursery lay-out and the spray schedule discussed on page 15, enough seedlings can be grown on each acre of nursery to furnish rootstocks for 50 to 100 acres of trees at field spacing. The seed gardens now being planted in the American Tropics will eventually furnish sources of disease-resistant seedlings. In the meantime, spraying offers a means of utilizing the millions of susceptible seeds produced annually by the mature hevea trees now growing in tropical American countries.

## SPRAYING AND DUSTING EXPERIMENTS IN SEEDLING NURSERIES

Under a cooperative arrangement between the United States Department of Agriculture and the Goodyear Rubber Plantations Co., the writer initiated spraying and dusting tests in the Goodyear seedling nurseries at All Weather Estate, Panama, in 1940. These tests were terminated in July 1941, and soon thereafter tests with some of the materials that had appeared particularly promising were undertaken at the United States Department of Agriculture Cooperative Rubber Plant Field Station, at Turrialba, Costa Rica, and at the Goodyear Co.'s Speedway Estate, at Cairo, Costa Rica.

### TESTS AT ALL WEATHER ESTATE, PANAMA

In the first series of tests carried out in Panama, the following groups of fungicides were tested on nursery seedlings: (1) Copper fungicides, (2) sulfur fungicides, and (3) organic fungicidal compounds. The first group included "insoluble" copper fungicides and bordeaux mixture made according to several different formulas, each varying in the content or ratio of lime and copper sulfate. In the second group, liquid lime-sulfur diluted to 1:40 and 1:100, three dry wettable sulfurs, and a sulfur paste were tested. The third group of compounds consisted of proprietary products not yet in general use as fungicides. They were expected to be of possible value in case the copper and sulfur fungicides proved too toxic for use on hevea plants. Since spray supplements are needed to improve the spreading and sticking properties of spray mixtures used on the waxy young leaves of rubber plants, seven spreaders and stickers were tested.

In the tests at All Weather Estate 7 half-acre plots containing approximately 15,000 seedlings each and 20 plots of 1,000 seedlings each were used in addition to unsprayed control plots. The large plots were sprayed with a power machine, which maintained a pressure of 300 pounds to the square inch, and the small plots were sprayed with a barrel pump at a pressure of 150 pounds. The intervals between spray applications varied from 5 to 14 days, the average being 9 days. In addition to the sprayed plots, 2 small plots of seedlings were dusted at weekly intervals, with a copper dust on one and a sulfur dust on the other. When the spraying and dusting tests were initiated, the seedlings were 2 months old and many of them had been completely defoliated. When the tests were terminated, the plants were 10 months old, and a high percentage of those in some sprayed plots had reached budding size. A brief account of the results obtained with the various fungicides, spreaders, and stickers follows.

## BORDEAUX MIXTURE

When 4–4–50 bordeaux mixture (4 pounds copper sulfate, 4 pounds stone lime, 50 gallons water) was applied to very young seedlings during clear dry weather, the first symptoms of spray injury appeared on young leaves almost immediately. Wilting, which began around the leaf margins, was followed by complete necrosis of some young leaves within a few hours. In mild cases no necrosis was apparent, but leaf size and subsequent growth in diameter of the plants was reduced. Little or no injury resulted from applications of bordeaux mixture during dull wet weather, and well-established plants always were injured less than very young seedlings. Mature leaves were not affected.

The nature of bordeaux mixture injury suggests that factors other than copper toxicity may be partially or wholly responsible for the damage resulting from some applications of this fungicide. High-lime bordeaux caused more injury than low-lime bordeaux of the same copper content; for example, 2–4–50 was more injurious than 2–1–50. The addition to bordeaux mixture of casein and wheat flour to improve its spreading and sticking properties increased the injury. Other tests revealed that some applications of milk-of-lime alone caused noticeable injury to young seedlings.

Since bordeaux mixture injury is seldom if ever as severe as leaf blight damage and since a high percentage of nursery seedlings can be brought to budding size by spraying with bordeaux mixture, it may be advantageously used in spraying hevea plants if more suitable fungicides are unavailable. In young seedling nurseries, 1–½–50 or 2–1–50 should be used in lieu of the more concentrated mixtures.

## "INSOLUBLE" COPPER FUNGICIDES

The "insoluble" copper fungicides gave better disease control than any other of the materials that caused no injury to the plants. Among the "insoluble" copper fungicides tested were one or more brands of each of the following materials: Basic copper sulfate, copper silicate, copper phosphate, copper oxychloride, and cuprous oxide. Extensive tests would be required to determine the relative effectiveness of the large variety of the brands. When a suitable spreader and sticker was added to the spray mixture, all those used in these tests gave good disease control; that is, few leaves were badly deformed by disease lesions, and only an occasional leaf flush was lost. Growth of most plants was not appreciably retarded by leaf blight.

## LIME-SULFUR

Liquid lime-sulfur used at a dilution of 1 part of commercial concentrate (specific gravity, 1.3) to 40 parts of water caused considerable injury to young seedlings. When used at a dilution of 1 to 100 injury was slight, but disease control was no better than that obtained by using wettable sulfur fungicides.

### WETTABLE SULFUR FUNGICIDES

Under the conditions of these tests, wettable sulfur fungicides gave good disease control. They were somewhat less effective, however, than the "insoluble" copper fungicides, especially during periods of rainy weather. The wettable sulfur fungicides purchased in dry form were fully as effective as the sulfur paste used and much more easily incorporated in spray mixture. During bright weather, combined sun-sulfur injury sometimes followed applications of these fungicides, though the damage was not severe under the conditions of these tests.

### ORGANIC FUNGICIDAL COMPOUNDS

Two organic fungicides were tested. Both gave less effective disease control than either the "insoluble" coppers or the wettable sulfurs.

### SPREADERS AND STICKERS

Materials tested as spreaders and stickers with an "insoluble" copper fungicide included the following: Casein, wheat flour, casein plus wheat flour, "Grasselli" spreader-sticker, potassium fish-oil soap, rosin-residue emulsion, a vegetable oil, and a mineral oil. Each of the last two materials had an emulsifying agent incorporated in it. Both, when used in the quantity recommended by the manufacturer, improved disease control, but they caused a distinct dwarfing of the plants. Casein plus wheat flour gave especially promising results.

### DUSTS

Weekly applications of either copper or sulfur dust gave partial disease control. In both cases, however, the degree of control was somewhat less than that obtained by spraying with similar fungicides.

### SUMMARY OF RESULTS

The preliminary tests in Panama indicated that leaf blight could be economically controlled in seedling nurseries by spraying with either "insoluble" copper or wettable sulfur fungicides. The addition of certain spreaders and stickers to the spray mixtures increased their effectiveness. Some of the spray materials that gave especially promising indications were tested further in Costa Rica during the following year.

## TESTS AT TURRIALBA, COSTA RICA

In November 1941, 13 plots were each planted with 1,000 disease-susceptible seedlings at Turrialba, Costa Rica. With the exception of plots Nos. 1 and 8, all were sprayed weekly with mixtures listed in table 1, the sprays being applied with a power machine at a pressure of 300 pounds. When the seedlings were 1 year old, diameter measurements were taken on all plants in each plot. The percentages of seedlings in each diameter class are shown in table 1.

Plants listed as three-fourths inch or more in diameter had reached the approximate minimum size at which they could be budded advantageously. Most plants one-half to three-fourths inch in diameter were brought to budding size by continuing the spray program for 3 additional months, while the greater part of the plants measuring less than half an inch could have been brought to budding size only by a prolonged period of spraying. In the unsprayed plot, 99 percent of the plants were less than half an inch in diameter, and more than 50 percent of them were dead (fig. 1).

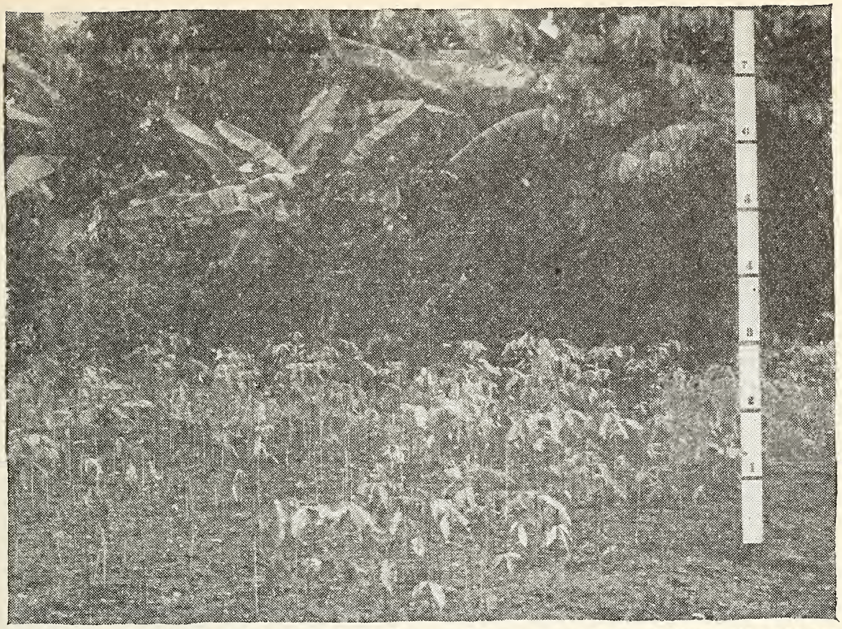

FIGURE 1.—Unsprayed 1-year-old seedlings of hevea growing at Turrialba, Costa Rica. Leaf blight has killed more than 50 percent of the plants in this plot.

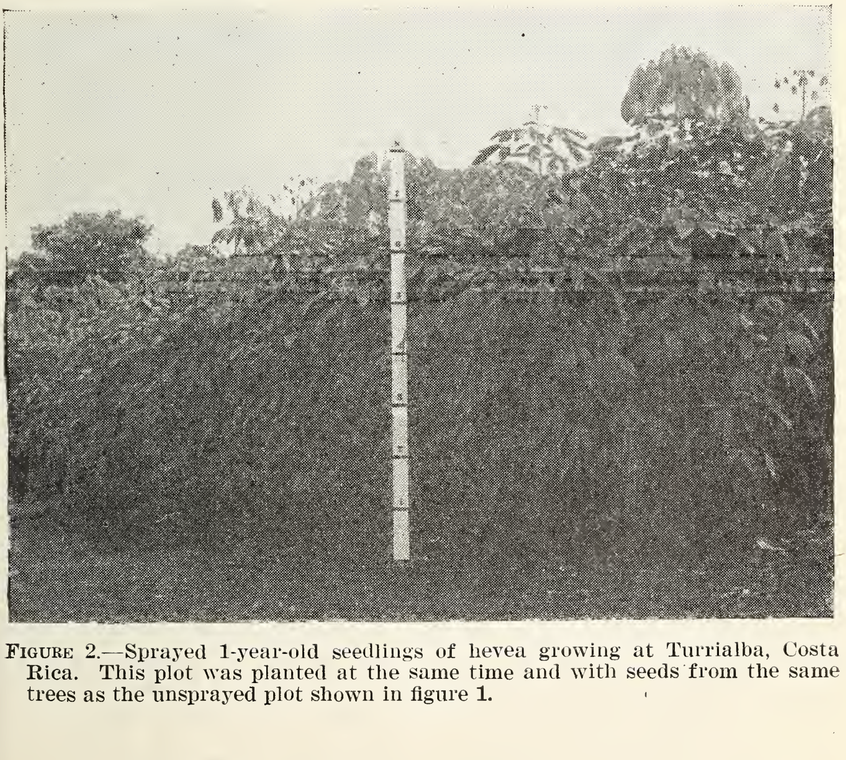

FIGURE 2.—Sprayed 1-year-old seedlings of hevea growing at Turrialba, Costa Rica. This plot was planted at the same time and with seeds from the same trees as the unsprayed plot shown in figure 1.

TABLE 1.—*Results of spraying tests for the control of leaf blight of hevea seedlings, Turrialba, Costa Rica, 1941–42*

| Plot No. | Spray formula[1] | | Plants by diameter classes[2] (inches) | | |
|---|---|---|---|---|---|
| | Fungicide | Spreader and sticker | ¾ or more | ½ to ¾ | Less than ½ |
| | | | *Percent* | *Percent* | *Percent* |
| 1 | Unsprayed | | 0 | 1 | 99 |
| 2 | Tennessee "34" copper, 2–100 | None | 49 | 29 | 22 |
| 3 | do | Cottonseed oil, 4–100 | 0 | 6 | 94 |
| 4 | do | Rosin-residue emulsion, 1–100 | 63 | 30 | 7 |
| 5 | do | Wheat flour, 2–100 | 49 | 38 | 13 |
| 6 | do | Casein, ½–100 | 56 | 34 | 10 |
| 7 | do | Casein, ¼–100 + flour, 2–100 | 64 | 30 | 6 |
| 8[3] | do | do | 34 | 33 | 33 |
| 9 | Tennessee "34" copper, 3–100 | do | 60 | 30 | 10 |
| 10 | Microgel, 1½–100 | do | 60 | 34 | 6 |
| 11 | Cuprocide, 1½–100 | do | 55 | 35 | 10 |
| 12 | "Mike" sulfur, 6–100 | do | 43 | 37 | 20 |
| 13 | Bordeaux mixture, 2–1–100 | None | 46 | 30 | 24 |

[1] Quantity expressed in pounds per 100 gallons of spray mixture.
[2] Diameter measurements, 4 inches above the soil, made when plants were 1 year old.
[3] Plot 8 sprayed 3 times a month; the others weekly.

The results obtained with different fungicides, spreaders, and stickers are in close agreement with those reported from the earlier tests in Panama. Table 1 shows that weekly applications of "insoluble" copper fungicides, to which rosin-residue emulsion, casein, or casein plus wheat flour were added, gave especially effective leaf blight control without stunting the plants. One year after the seeds were planted plots sprayed with these materials contained 55 to 64 percent buddable plants, and 3 months later the percentage had risen to more than 85. The 1-year-old plants in plot 7 averaged almost 7 feet in height, as compared with 1½ feet for the unsprayed plants (figs. 1 and 2). Although rosin-residue emulsion gave excellent results when used in small quantity in spraying test plots, a gummy substance, which completely fouled the spray pump, was formed when it was tested more extensively with "insoluble" copper fungicides. This difficulty did not arise when rosin-residue emulsion was tested with sulfur fungicides.

A comparison of plots 7 and 9 (table 1) shows that nothing was gained by increasing from 2 to 3 pounds per 100 gallons the dosage of Tennessee "34" copper fungicide (34 percent copper as metallic). Leaves on plants sprayed with the higher dosage were somewhat reduced in size. Further tests now in progress with this fungicide indicate that 2 pounds is more satisfactory than either 1 or 3 pounds per 100 gallons.

Plot 3, which was sprayed with an "insoluble" copper fungicide plus cottonseed oil containing an emulsifying agent, was almost disease free, but the plants were so severely stunted that none reached budding size within a year. Other tests revealed that weekly applications of this oil mixed with water, but containing no fungicide, greatly reduced the growth of young hevea plants. Even when used at a concentration one-fourth as great as that recommended by the manufacturer, some stunting of young hevea plants eventually resulted from weekly applications of this oil mixed with water.

A comparison of plots 7 and 8 shows that under the conditions of these tests weekly spray applications were in the long run more economical than those spaced at wider intervals.

The "insoluble" copper fungicides gave better disease control than the wettable sulfur used in this test. Leaf blight, however, was effectively controlled during the greater part of the year by weekly applications of wettable sulfur, and it should be noted that plot 12, which received weekly applications of sulfur fungicide, produced a slightly higher percentage of buddable seedlings than plot 8, which was sprayed with copper fungicide three times a month. Observations indicate that wettable sulfur-spray residues are washed off the plants more quickly than "insoluble" copper residues. Thus, it is not surprising that for equal disease control sulfur sprays must be applied somewhat more frequently than copper sprays. If copper fungicides become temporarily unavailable, however, wettable sulfurs may be used to good advantage.

Recent preliminary tests have indicated that Fermate (ferric-dimethyl-dithiocarbamate), an organic fungicide containing a minimum of materials essential in the manufacture of armaments, is a very effective substitute for "insoluble" copper fungicides. This fungicide should be used at the approximate rate of 1½ pounds to 100 gallons of water. It may be used in combination with an equal weight of lime or with the spreaders and stickers that have increased the effectiveness of "insoluble" copper fungicides (table 1).

A test apart from those previously described was conducted with 6,000 small, defoliated, 1-year-old seedlings at Turrialba. With weekly spray applications of "insoluble" copper fungicide for 8 months, most of these plants were brought to budding size. It is emphasized, however, that the most economical disease control is attained by beginning to spray the plants at suitable intervals as soon as the disease appears in the nursery.

### TESTS AT CAIRO, COSTA RICA

In cooperation with the Goodyear Rubber Plantations Co., spraying was tested on a large scale at Cairo, Costa Rica, during 1941–42. Applications at 8- to 10-day intervals of an "insoluble" copper fungicide plus a spreader and sticker (2 pounds copper fungicide, ¼ pound casein, and 2 pounds wheat flour to 100 gallons of spray mixture) gave excellent disease control in a nursery of almost 500,000 seedlings. During a period of exceptionally rainy weather, when no spray was applied for 3 weeks, the new flushes of leaves were badly damaged by leaf blight. Five spray applications during the succeeding month brought the disease under control, and the plants soon regained their original vigor. Measurements on the 1-year-old seedlings showed that while only 18 percent of the plants in an unsprayed plot had reached budding size, 70 percent of those in a nearby sprayed plot were buddable.

### SUMMARY OF RESULTS IN PANAMA AND COSTA RICA

In summarizing the results of spraying tests at All Weather Estate, Panama, and at Cairo, Costa Rica, it should be noted that approximately 70 percent of the sprayed seedlings, but only 15 to 20 percent of the unsprayed seedlings, reached budding size within 1 year. At Turrialba, Costa Rica, a locality offering very favorable conditions for leaf blight development, spraying increased the percentage of buddable 1-year-old seedlings from zero to more than 60 percent.

## FACTORS AFFECTING CONTROL BY SPRAYING

In a seedling nursery, the young, blight-susceptible leaves constantly unfolding become resistant to leaf blight when approximately 2 weeks old. If infected before reaching this age, spore-producing lesions appear after about 1 week. By maintaining a protective film of spray on all young leaves, disease damage could be eliminated; but since leaf expansion is rapid and new leaves are emerging on some plants in a nursery at all times, very frequent spray applications would be required for complete disease control by protective spray films.

In actual practice spraying lessens the incidence of disease by (1) inactivating the spores on diseased leaves and stems and (2) spreading a protective film over young susceptible leaves. Germination tests have shown that whereas very few viable leaf blight spores can be washed from diseased hevea leaves picked from a nursery that was sprayed with copper fungicide 5 days earlier, unsprayed leaves of similar age and condition were yielding tens of thousands of viable spores. Obviously, if the sprayed nursery is located immediately adjacent to badly diseased, unsprayed plants, the advantage of a small viable spore population resulting from spray residue on the diseased leaves is largely nullified. Therefore, the location of the sprayed nursery with reference to diseased plantings, which serve as sources of wind-borne inoculum, is an important factor in determining the time of the first and the frequency of subsequent spray applications.

Field tests have demonstrated the importance of locating a new nursery at some distance from large groups of badly diseased hevea plants. At All Weather Estate a nursery of about 1,000 blight-susceptible seedlings was planted beside a badly diseased 1-year-old nursery. On the same day a similar nursery was planted 500 yards from the nearest hevea trees. Neither of these nurseries was sprayed. Whereas a high incidence of disease developed in the former nursery as soon as the seedlings emerged from the soil, leaf blight did not appear in the more distant nursery until the plants were several weeks old. It then spread gradually from a few initial infections and caused no severe damage until the seedlings were almost 2 months old. Tests at both All Weather Estate and Turrialba have shown that spray applications at intervals frequent enough to give excellent disease control in a nursery located a few hundred yards from any diseased hevea planting may give poor disease control in a nursery growing adjacent to a blight-infested planting.

Although it is evident that the elimination of sources of disease inoculum immediately adjacent to the sprayed nursery is an effective complementary disease-control measure, the suppression of blight damage in nurseries of susceptible seedlings over a long period requires the application of sprays. Preferably, these sprays should be applied soon enough and frequently enough to maintain a low incidence of disease in the nursery.

## EFFECT OF SPRAY RESIDUES ON BUDDING SUCCESS

A high percentage of failures in budding sprayed plants may often raise the question of possible detrimental effects of spray residues. To investigate this possibility, the tests described below were conducted at Turrialba, Costa Rica. In considering the results of these tests, the distinction between sprayed seedlings and sprayed budwood should be kept clearly in mind. As used herein, sprayed seedlings refer to sprayed plants that are used as rootstocks; sprayed budwood refers to sprayed plants from which budwood, and ultimately the bud patches, are cut.

### Budding Tests on Sprayed Seedlings

During September and October 1942, 1,200 seedlings were used in tests to determine whether budding success was lowered by copper-spray residues. In test 1, a group of 10-month-old seedlings sprayed weekly with an "insoluble" copper fungicide was compared with a group of seedlings of similar age and size sprayed weekly with wettable sulfur. In test 2, 10-month-old seedlings sprayed weekly with an "insoluble" copper fungicide were compared with similar seedlings from which the copper-spray residue was washed with 0.3 percent hydrochloric acid followed by a rinse with water. In test 3, 18-month-old seedlings sprayed with an "insoluble" copper fungicide were compared with similar unsprayed seedlings. The seedlings used in test 3 were semiresistant plants that had grown to budding size without being sprayed. The group of these plants designated as sprayed seedlings was thoroughly covered with copper fungicide down to the ground line approximately 1 hour before they were budded. They, therefore, had a much heavier copper-spray residue on their lower stem region than is ordinarily found on sprayed seedlings where only the blight-susceptible, topmost flush of leaves is sprayed.

On each of the 6 groups of seedlings described in the preceding paragraph, 50 buddings were made by the same budder, using brown budwood of the same clones. The tests were repeated each week for 4 weeks, thus making a total of 200 buddings on each group of plants. The percentage of successful buddings, or "takes," for each group of 200 plants compared in tests 1 to 3 was as follows: (1) Copper-sprayed seedlings, 39; sulfur-sprayed seedlings, 35. (2) Copper-sprayed seedlings, 60; copper-sprayed seedlings with residue removed, 56. (3) Copper-sprayed seedlings, 56; unsprayed seedlings, 59. The rather low percentage of successful buddings obtained in all tests conducted during this period is attributed to extremely wet weather, and the very low percentage obtained in test 1 resulted, in part, from the use of small, relatively poor plants. In addition to these specific tests, several thousand buddings made during 1942 in a copper-sprayed nursery at Turrialba gave a slightly higher percentage of "takes" than was obtained during the same period in an unsprayed nursery of semiresistant seedlings. During March 1943 several of the plots of copper-sprayed seedlings listed in table 1 were budded with freshly cut budwood from a large variety of clones. The percentage of successful buddings averaged above 90.

None of the budding results at Turrialba have indicated that spray residues on sprayed seedlings cause budding failures.

Attention is called to the fact that only the topmost, or blight-susceptible, leaf flushes of nursery seedlings are sprayed; thus, on seedlings that have reached budding size, little spray residue is usually found on the lower stem portion of the plants. Any loose particles of spray residue would likely be brushed off by the customary brushing of the lower stem of seedlings to remove soil particles before they are budded. Any spray residue that remains is on the outer side of the flap, where it is unlikely to cause damage. The use of sprayed budwood, which is discussed below, presents different problems, the chief one being the insertion of the residue-covered bud patch beneath the flap of the seedling plant.

### Tests with Budwood from Sprayed Plants

Early in 1942, E. T. Stanwood, of the United States Department of Agriculture Cooperative Rubber Plant Field Station in Honduras, reported a very low percentage of successful buddings from budwood cut from plants sprayed with bordeaux mixture and at the same time a high percentage from budwood of the same clones from unsprayed plants. To investigate further the detrimental effect of spray residues on budwood, tests were conducted by the writer at Turrialba, Costa Rica, in September and October 1942.

Using brown budwood of the same clone, 50 buddings from each of 4 classes were made weekly for 4 weeks by the same budder, and the percentage of "takes" for the 200 buddings from each class was as follows: (1) Unsprayed budwood, 60; (2) budwood sprayed with a wettable sulfur fungicide, 67; (3) budwood sprayed with an "insoluble" copper fungicide, 20; and (4) budwood sprayed with 2–2–50 bordeaux mixture, 12. These tests confirm Stanwood's findings as regards the detrimental effect of bordeaux-spray residue on budwood. They also indicate injury from "insoluble" copper-spray residues. In each of the 4 repetitions of the tests, the percentage of "takes" obtained with "insoluble" copper or bordeaux-sprayed budwood was lower than that from unsprayed budwood. The higher percentage of successful buddings obtained from sulfur-sprayed budwood than from unsprayed budwood resulted from an unusually high percentage of "takes" in one case, rather than consistently higher percentages in several. This difference between sulfur-sprayed and unsprayed budwood is not considered significant.

Stanwood found that the detrimental effect of bordeaux-spray residue could be remedied to a large extent at least by immersing the budwood in 0.3 percent hydrochloric acid for 3 seconds and following this immediately by a thorough rinsing in running water. In washing, the budwood should be handled carefully to avoid bruises.

Although the above method of avoiding low budding success from copper-spray residue on budwood may be followed, the simplest procedure appears to lie in the use of wettable sulfur fungicides, rather than copper fungicides, in spraying plants that are to be used as budwood. No injury, however, is likely to result from the use of copper sprays if a change to sulfur is made early enough for rain to remove the copper residues.

## SPRAYING HIGH-YIELDING CLONES

Soon after the study of fungicidal control of leaf blight in seedling nurseries was begun, the growing popularity of double-budded, or three-component, trees (*6*, *8*, *12*) encouraged tests to determine the feasibility of spraying high-yielding, disease-susceptible budded plants until they reach a size suitable for top-budding (fig. 3). The high-yielding hevea clones developed by many years of selection in the Orient, where leaf blight does not yet occur, are all susceptible to this disease. They may be advantageously used, however, by applying the double-budding procedure. The resulting three-component tree should consist of a vigorous disease-resistant rootstock (fig. 3, *a*) budded with a high-yielding clone to form the stem (fig. 3, *b*), which in turn is budded at a height of 6 or 7 feet with a pest-resistant and wind-resistant clone to form the top (fig. 3, *c*). After the seeds are planted, approximately 1 year must elapse before the first budding is done. An additional year's growth is required between the first and second budding operations. During this interval, the young trees will require spraying in some localities for leaf blight control. Tests that have indicated the feasibility of spraying these young trees have been conducted in Panama and Costa Rica.

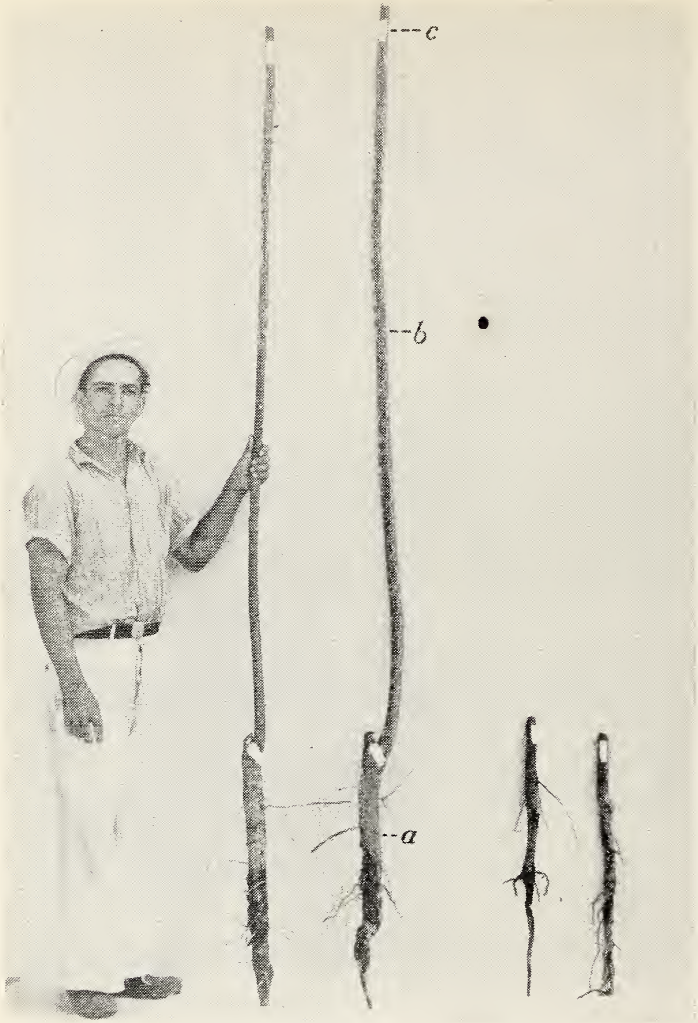

FIGURE 3.—Top-budded or double-budded stumps of hevea. The points at which buds were inserted (lower ones a year before) are marked in white. These three-component trees consist of *a*, seedling rootstock; *b*, high-yielding stem; and *c*, blight-resistant top bud. On the right, two low-budded stumps are shown for comparison.

When the double-budding procedure is utilized, the usual operation of grafting a high-yielding clonal bud on a seedling plant at a height of 3 or 4 inches above the soil is carried out. From this point either of two procedures may be followed: (1) The budded stumps may be transplanted to the field and grown there until they are large enough to be top-budded, or (2) the budded stumps may be grown in the nursery until they have been top-budded, then transplanted to the field as high-budded stumps (fig. 3). In a small-scale experiment to test these two procedures, three high-yielding Eastern clones were used to form the stem portion of the trees. Blight-resistant clones will be used for the crowns. The early phases of this experiment are described below.

In May 1942, 108 stumps budded with high-yielding, blight-susceptible Eastern clones were transplanted to a half-acre field plot at a spacing of 10 by 20 feet. Approximately 200 stumps budded with the same clones were allowed to grow in a nearby nursery bed. Both plantings were sprayed weekly with an "insoluble" copper fungicide, a knapsack sprayer being used for plants at field spacing and a power machine for those at nursery spacing (figs. 4 and 5). Disease control on these highly susceptible plants has been excellent in both cases. When the plants have partially brown bark up to a height of 6 or 7 feet, they will be top-budded with blight-resistant clones. Those growing in the nursery row will then be transplanted to the field, while those now growing in the field will be allowed to remain in place.

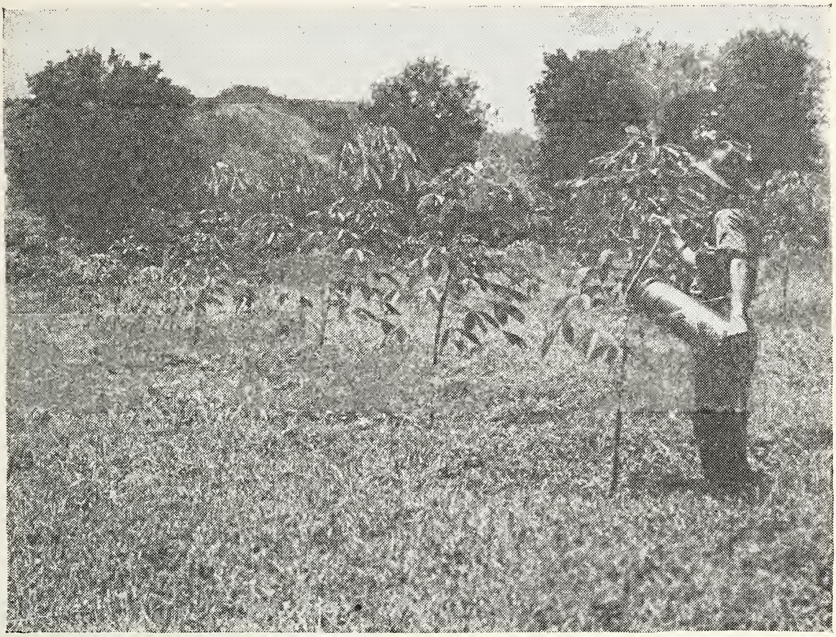

Figure 4.—Spraying high-yielding, blight-susceptible plants of hevea with a knapsack sprayer. Only the immature leaves need be sprayed. Within a few months these 10-month-old, field-spaced plants will be top-budded with disease-resistant clones, and spraying can then be discontinued. Turrialba, Costa Rica, 1943.

Although the above test has not yet been concluded, the feasibility and low cost of spraying young rubber plants growing either at nursery or field spacing has been demonstrated by this and a number of similar or related tests. Disease control on plants at nursery spacing may be somewhat less expensive than on those at field spacing, but since only the young leaves need be sprayed, and since, prior to top budding, the plants will have no more than one flush of young, susceptible leaves at any given time, the spraying of plants at field spacing is not a very expensive operation. Repeated tests have shown that one man with a knapsack sprayer can cover 10 to 20 acres daily. The consumption of spray materials per plant is lower for the plants growing at field spacing than in the nursery because of the fewer applications usually required by the former.

In some localities where climatic conditions are not especially favorable for leaf blight, the high-yielding, blight-susceptible clones can be grown at field spacing without spraying until they reach top-budding size. Good initial growth of these small trees, however, does not mean that they will continue to make satisfactory growth under their susceptible tops. Observations in a number of rubber plantings have shown that as the young trees increase in size, thereby increasing the quantity and density of foliage and the proximity of the foliage of one tree to

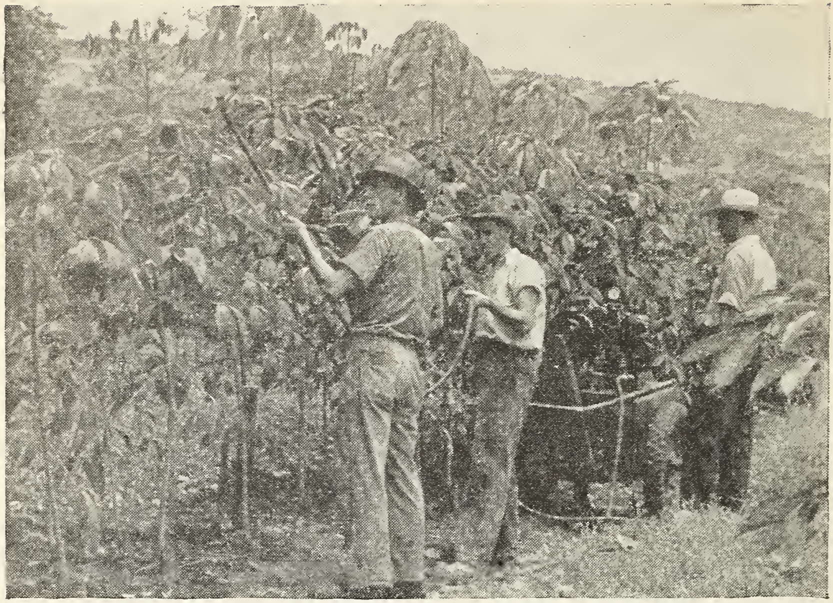

FIGURE 5.—Equipment used in spraying high-yielding, blight-susceptible plants of hevea growing in the nursery. After these plants are top-budded, the stumps will be transplanted to the field. Losses in transplanting high stumps make the procedure illustrated in figure 4 appear to be preferable. Turrialba, Costa Rica, 1943.

that of another, conditions for disease development and spread are constantly more favorable, and disease severity gradually increases. In many instances large areas of high-yielding, blight-susceptible trees that were in a vigorous growing condition when they had reached top-budding size at the age of 1 to 2 years were, in the absence of top budding with highly resistant clones, destroyed by leaf blight at the age of 5 or 6 years.

In limited tests on transplanting top-budded stumps (fig. 3), a high percentage of the top buds has been lost as a result of dieback. Procedures that would be likely to lower these losses would also increase transplanting costs. On the other hand, top budding in the field has been successfully demonstrated on a large scale (*6, 12*). The procedure of transplanting the low-budded stumps to the field, protecting them against blight by use of knapsack sprayers if necessary, and then top budding them in the field when 1 year old appears to be entirely feasible.

## SPRAYING TREES DURING THE ANNUAL LEAF-CHANGE PERIOD

Since hevea leaves are susceptible to leaf blight only until they are about 2 weeks old, the period of annual leaf change is of particular importance. Stahel (*13*) has shown that two or three successive defoliations deplete the starch reserves of 5- or 6-year-old trees, thereby causing them to die. Trees that are protected from defoliation when developing their new set of leaves during the leaf-change period may be expected to carry on during the following year, though their growth may be hampered by the loss of new leaves from growing terminal shoots. To determine the effect of spray applications during this period on the behavior of trees during the ensuing year, the following test was carried out at All Weather Estate.

During March 1941, 5 applications of copper fungicide were made on a group of 40 closely planted, blight-susceptible, 5-year-old trees. The first spray was applied when the new leaves began to appear after the annual leaf drop, and subsequent applications followed at 4- to 6-day intervals. These sprayed trees held approximately 90 percent of their leaves, whereas similar unsprayed trees were repeatedly defoliated and as a consequence suffered from dieback. The condition of the sprayed trees during the ensuing year could not be described as vigorous, but no dieback occurred on them. Had it been possible to eliminate the inoculum from badly diseased nearby trees, the 5 spray applications would doubtless have resulted in more thorough disease control.

With satisfactory equipment, leaf blight could be controlled in field plantings of producing trees by spraying. It is likely, however, that the type of equipment and the frequency of spray applications required to maintain a healthy growing condition would make the cost prohibitive. In breeding gardens, when crossing high-yielding, blight-susceptible clones and highly resistant clones, spraying appears to be a feasible means of controlling leaf blight on the former group. The availability of blight-resistant clones and the low cost of top budding high-yielding Eastern clones make the spraying of large trees unnecessary as a commercial practice.

# PROCEDURES RECOMMENDED IN SPRAYING

## LAYING OUT AND SPRAYING THE NURSERY

The tests reported in the foregoing section have demonstrated that leaf blight can be effectively and economically controlled in seedling nurseries by spraying. Both the effectiveness and the cost of spraying will depend to a large extent on the location of the nursery, the manner in which it is laid out, and the kind of spray equipment and materials used. Some important practical points that should receive consideration in the spray program are here presented.

### LOCATION OF THE NURSERY

The desirability is well recognized of choosing a conveniently located nursery site having a deep, fertile, well-drained soil, with few stones to interfere with the digging of budded stumps. Certain other location factors, however, should receive special consideration. These are (1) proximity of diseased hevea plantings and (2) nearness to a source of water.

Since there are now few hevea plantings in tropical America and since only blight-resistant clones or high-yielding, susceptible clones that will be top-budded with blight-resistant material are recommended for use in field plantings, the main thing to avoid in connection with factor 1 above is the planting of a new nursery beside one that is badly diseased and abandoned. If the most convenient site for the new nursery is adjacent to one that is old and diseased, the old plants, if their value does not warrant disease control by spraying, should be removed before the young seedlings emerge from the soil. Tests that have demonstrated the detrimental effect of nearby sources of disease inoculum on sprayed nursery seedlings are described on page 9.

Nurseries of highly susceptible seedlings in many localities will require weekly spray applications. As 100 to 250 gallons of spray mixture to the acre is required for effective coverage at each application, the importance of a source of water near the nursery is apparent.

### LAYING OUT THE NURSERY

Hevea seedlings are usually planted on nursery beds 4 or 5 feet wide and of variable length. Often the length is determined by the contour of the land. Since the time required to spray a nursery as well as the thoroughness with which it can be sprayed will depend to a large extent on the manner in which it is laid out, this point should receive due consideration.

The nursery lay-out shown in figures 6 and 7 is well adapted to the use of a mobile spray machine. In this nursery the beds, each 5 by 80 feet in size and separated by 2-foot drains, run at right angles to and on both sides of a road. As the machine is drawn along the road the plants in the beds on both sides can be sprayed from the drains by using a 100-foot hose. The seedlings are spaced 1 foot apart in either direction in the beds. Thus, four rows of seedlings can be planted the length of each bed, and a border 1 foot wide will be left on both sides of it (fig. 8).

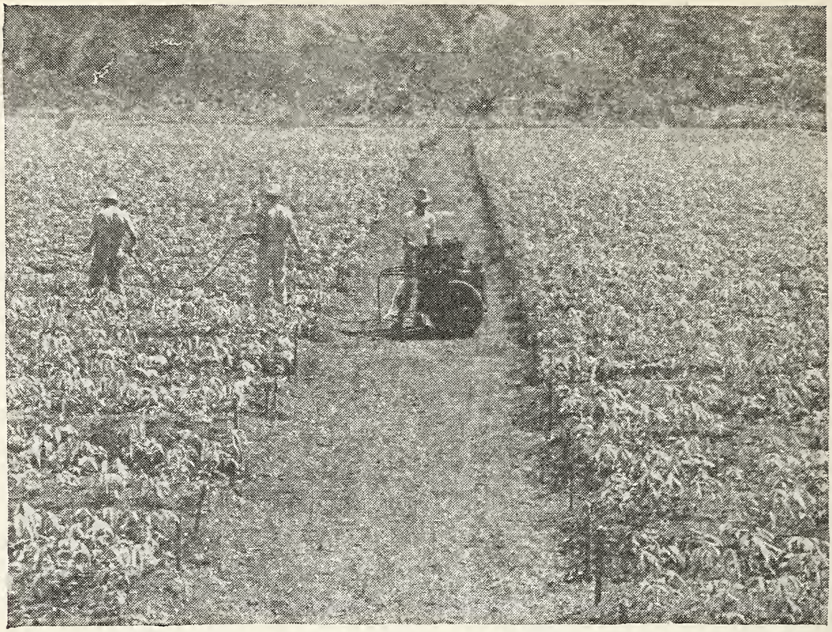

FIGURE 6.—View of a seedling nursery of hevea at Turrialba, Costa Rica, showing a convenient lay-out for spraying with a mobile machine. The plants in beds are sprayed on either side by men carrying hose as they walk along the drains, which run at right angles to the road (see fig. 7).

In nurseries laid out according to the plan described, the distance from the plants of one bed to those of the other is 4 feet. Figure 7 shows that this is more than ample to permit the spraying of young plants. It is, however, a bare minimum for the effective spraying of 1-year-old plants such as those shown in figure 2. If, in spite of the distance between beds of plants, some leaves project out over the drains far enough to close in above them, cutting these leaves will greatly facilitate spraying, with little or no damage to the plants. Wide drains, kept open for use as paths, facilitate budding and stump-digging operations as well as spraying.

Spraying in nurseries having a poor stand of plants is wasteful of both time and materials. Therefore, in planting a nursery that is to be sprayed, the seeds, unless of known high viability, should be put into germination beds and planted in the nursery as they germinate. This not only gives a better stand but also simplifies spraying by starting all plants in a given bed of seedlings at approximately the same height.

## EQUIPMENT AND MATERIALS NEEDED

The most economical type of spray equipment to use depends on the size of the nursery. For a nursery of 1,000 to 2,000 plants an inexpensive knapsack sprayer of the type shown in figure 4 is adequate. A barrel pump may prove satisfactory for nurseries ranging up to several thousand plants. Power machines developing at least 300 pounds pressure give the most effective spray coverage and are likely to prove most economical in nurseries of many thousand plants. A small power machine of the type shown in figure 6 has sufficient capacity to spray from 50,000 to 100,000 seedlings a day, or, with applications spaced at 7-day intervals, to maintain a nursery of a few hundred thousand plants. A triple-nozzle spray gun with No. 3 disks has proved very satisfactory for spraying nursery seedlings with a power machine.

The relative disease control obtained in tests with various fungicides, spreaders, and stickers has been discussed on page 7. The "insoluble" copper fungi-

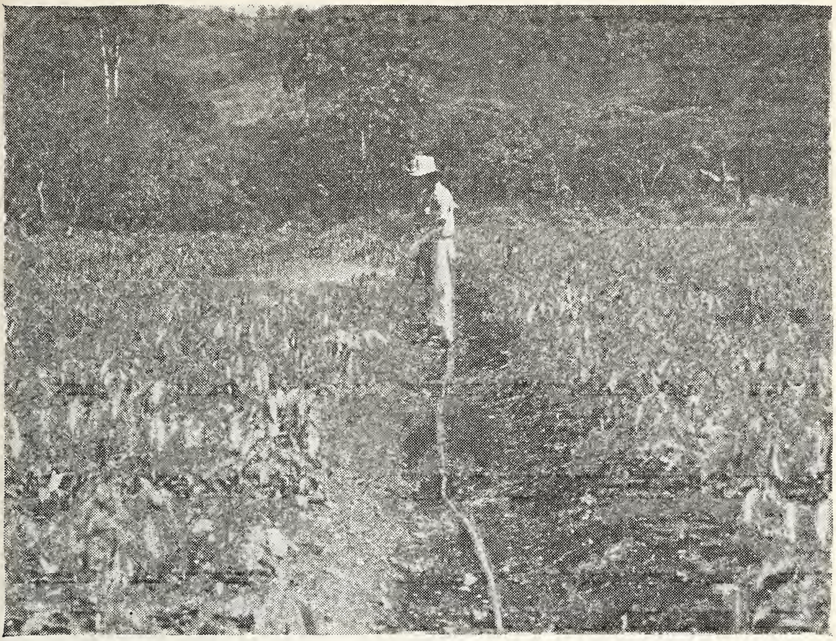

FIGURE 7.—Spraying nursery seedlings of hevea at Turrialba, Costa Rica. The bed of seedlings now being sprayed will also be sprayed from the drain on its left side, the gun operator moving in the opposite direction from that shown.

cides have given more satisfactory results than other materials that have been thoroughly tested, but should the copper fungicides become temporarily unavailable, effective disease control can be obtained by somewhat more frequent applications of wettable sulfur fungicides. In preliminary tests Fermate used at the rate of 1½ pounds to 100 gallons of spray mixture has given as effective disease control as that obtained with "insoluble" coppers. In general, the "insoluble" copper fungicides should be used at the rate of about 2 pounds per 100 gallons of spray mixture and the wettable sulfurs at the rate of about 6 pounds to 100 gallons. In the tests conducted by the writer either 150 to 250 pounds of "insoluble" copper fungicide or 600 to 1,000 pounds of wettable sulfur has been required to bring each acre of disease-susceptible nursery seedlings to budding size.

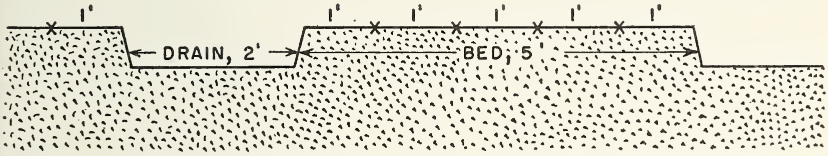

FIGURE 8.—Cross section of a nursery bed, showing a desirable spacing of plants (indicated by ×) and width of drains where spraying is practiced.

The addition of certain spreaders and stickers to the spray mixture increases its effectiveness. Casein plus wheat flour used in the proportion shown in table 1 has given especially promising results when used with "insoluble" copper fungicides or wettable sulfurs. Casein alone used at the rate of ½ pound to 100 gallons of spray mixture is only slightly less effective. Before casein is added to the spray mixture it should be vigorously stirred in water, to which are then added a few drops or crystals of a strong alkali (ammonium hydroxide, sodium hydroxide, or "lye" may be used). Rosin emulsion may be used with wettable sulfur fungicides. The oil spreaders and stickers that have been tested have stunted young hevea plants when used weekly over a long period.

If directions for mixing are not given by the manufacturer of the spray materials, the common procedure of adding the fungicide to the partially filled tank and following this with the supplementary materials will usually give good results. The mixture should be agitated as the separate ingredients are added.

### INTERVALS BETWEEN APPLICATIONS

The frequency of spray applications in the nursery depends on susceptibility of plants, weather conditions, location of nursery with reference to sources of disease inoculum, spray materials used, thoroughness of coverage, and other factors. Semiresistant seedlings growing in localities that offer only moderately favorable conditions for disease development may make satisfactory growth without being sprayed at all. In areas where leaf blight occurs, however, seedlings from most sources in tropical America must be sprayed to prevent a high percentage of loss.

Tests already reported (p. 8) have shown that weekly applications of some spray mixtures give excellent disease control on highly susceptible seedlings growing under very favorable conditions for leaf blight (figs. 1 and 2). In other localities, where conditions for disease development are less favorable, spray applications at 8- to 10-day intervals have given good control. On the other hand, if spraying is begun in a badly diseased nursery, it appears desirable to spray at 5- or 6-day intervals until the disease is brought under control. In some localities the intervals between spray applications might be extended during the dry season; in others this will not be possible because heavy dews cause an increase in disease severity.

If the new nursery is planted near diseased hevea plants, the first spray should be applied as soon as the young seedlings emerge from the soil. If, however, the nearest diseased plants are several hundred yards away, spraying may be postponed until leaf blight makes its appearance.

### METHOD OF SPRAYING

Only young hevea leaves are susceptible to leaf blight; thus, in general, only the topmost flush of leaves of nursery plants need be sprayed. An exception to this rule should be made when spraying is first begun in a blight-infested nursery. In this case, the first few applications should cover all diseased leaves in order to inactivate the spores they are producing.

Leaf-blight infections may occur on either the upper or the lower surface of young leaves, and spores are produced by lesions on both surfaces. For effective control of this disease, therefore, it is essential to cover both the upper and the lower surfaces of young leaves. This can be accomplished best by tilting the spray gun so that the nozzle points slightly upward and by spraying the seedlings of each bed from both of its drains, preferably from the drain on one side while moving in one direction and from the drain on the other side while moving in the opposite direction (fig. 7). The plants should not be so drenched that the spray drips from the leaves. To "fog" them requires less material and is more effective.

The efficiency with which sprays can be applied decreases with increasing wind velocity. Spraying, therefore, is preferably done while the wind is not blowing Should this be impractical, the greater part of the spray should be applied with the force from the nozzle directed against the wind. Spraying with the wind can at best wet only one side of the plants.

Spray applications on plants that are wet from rain or dew are only partially effective. To obtain the maximum benefit, the application must be made when the foliage is dry, and the spray must dry on the leaves before rain falls.

## SPRAYING CLONAL PLANTS

The spraying of high-yielding, blight-susceptible clones until they reach a size suitable for top budding with clones that are disease resistant is discussed on page 11. The methods and materials that have controlled disease most effectively and inexpensively in seedling nurseries can, in general, be applied in spraying clonal plants. There are, however, one or two important exceptions.

In contrast with the close spacing of nursery seedlings, budded stumps will usually be grown at field spacing to prevent losses in transplanting the tall, top-budded stumps. To spray small plants growing at a spacing of 7 by 20 feet or wider, light equipment is needed. Thus, knapsack sprayers of the type shown in figure 4 have proved more satisfactory than the heavier rolling machines. The fact is again stressed that if sprays are regularly applied, only the immature leaves need be treated. Since new hevea leaves emerge in flushes at 6- to 8-week intervals, a high percentage of the plants have no young leaves at any given time and do not need to be sprayed.

During the first year, widely spaced young plants growing in the field are not so severely attacked by leaf blight as are the closely spaced plants growing in the nursery. Therefore, in some areas no spraying may be required to bring field-spaced, high-yielding, susceptible clones to top-budding size. In other areas, two to four applications a month may be required to assure healthy growth. Even though young susceptible trees may grow satisfactorily in some localities for a year or more without being sprayed, they should be top-budded with resistant clones as soon as they have reached a suitable size.

One man using a knapsack sprayer can spray 10 to 20 acres of young field-spaced plants in a day. Thus, under ordinary conditions, he will be able to spray an area of approximately 100 acres frequently enough to keep it in good growing condition. A maximum of about 6 pounds of Fermate, or 6 pounds of "insoluble" copper fungicide, or 20 to 30 pounds of wettable sulfur will be required to spray each acre of field-spaced rubbertrees until they reach top-budding size. When using knapsack sprayers, time is usually saved by making the spray mixture in 50- or 100-gallon tanks at central locations. Each time before the sprayer is filled, the mixture in the tank should be vigorously stirred. While the spraying is in progress, the knapsack sprayer should be shaken at frequent intervals to keep the fungicide from settling out.

Tests have indicated that with adequate equipment, several spray applications during the annual leaf-change period would protect blight-susceptible producing trees well enough to insure their survival. It is likely, however, that the cost of this operation would make it uneconomical as a commercial practice. The planting of highly resistant clones that have indicated a moderate yield or high-yielding susceptible clones protected by spraying and subsequently top-budded with resistant clones offers the greatest promise for successful hevea plantings prior to the time when high-yielding, disease-resistant clones have been selected, multiplied, and distributed.

## COST OF SPRAYING

The large number of spray applications required to protect highly susceptible hevea seedlings against leaf blight for a year makes the cost per acre rather high. When, however, the nursery cost per acre is spread over the many acres for which rootstocks will be provided for the field planting, nursery spraying is not a costly operation.

According to the lay-out of the nursery previously outlined (p. 15), approximately 25,000 germinated hevea seeds are planted to the acre. After ample allowance is made for normal losses, well over 50 percent of these germinated seeds might be expected to become buddable plants within 12 to 15 months. One acre of nursery, therefore, can supply enough rootstocks for at least 50 acres of rubber at field spacing.

Even in areas where a considerable percentage of the nursery seedlings will reach budding size without being sprayed, several factors in addition to the greatly increased production of buddable rootstocks make blight control by spraying a paying practice. Foremost among these are reduced weeding and budding costs, both of which are major items of nursery expenses.

Whereas healthy 6-month-old sprayed seedlings shade the ground completely enough to inhibit any further growth of grass and weeds, unsprayed plants, when not completely ruined by leaf blight, often have their foliage so reduced that grass and weeds continue to grow. Weeding, therefore, must be continued until these slowly developing plants are budded at the age of 1 to 3 years.

A high percentage of successful buddings is seldom obtained on weak, diseased plants. In improving the condition of nursery seedlings by spraying, the percentage of successful buddings is indirectly, but usually strikingly, increased.

Although the control of South American leaf blight was the objective of the tests here discussed, certain other lesser pests have been controlled or repelled by applications of copper fungicides. A species of caterpillar that commonly feeds upon the immature leaves of young hevea plants is never found on sprayed plants, and the destructive leaf-cutting ants appear to be repelled, at least to a great extent, by frequent applications of copper fungicide.

From limited tests conducted under Turrialba conditions the cost of labor and materials to protect field-spaced, high-yielding, susceptible trees until they reach top-budding size has been computed at less than $5 an acre.

## LITERATURE CITED

(1) BANCROFT, C. K.
1916. REPORT ON THE SOUTH AMERICAN LEAF DISEASE OF THE PARA RUBBER TREE. Brit. Guiana Dept. Agr., Agr. Jour. Brit. Guiana 10: 13–33. (From Off. Gaz. (Brit. Guiana), No. 228.)

(2) BLANDIN, J. J.
1941. WHY RUBBER IS COMING HOME. U. S. For. Agr. Rel., Agr. Amer. 1 (4) : 1–10, illus.

(3) BRANDES, E. W.
1941. RUBBER ON THE REBOUND—EAST TO WEST. U. S. For. Agr. Rel., Agr. Amer. 1 (3) : 1–11, illus.

(4) CAMARGO, F. C.
1941. RESEARCH IN TROPICAL BRAZIL. U. S. For. Agr. Rel., Agr. Amer. 1 (12) : 1–5, illus.

(5) FENNELL, T. A.
1941. HAITI MAKES RUBBER HISTORY. U. S. For. Agr. Rel., Agr. Amer. 1 (6) : 7–11, 15, illus.

(6) JOHNSTON, A.
1941. THE FORD RUBBER PLANTATIONS. India Rubber World 104 (2) : 35–38; (3) : 45–48.

(7) KUYPER, J.
1911. EINE HEVEABLATTKRANKHEIT IN SURINAM. *In* Rec. des Trav. Bot. Nëerland. 8: 371–380, illus. (Dutch ed. without Latin diagnosis in Suriname Dept. Landb. Bul. 28, pp. 3–10, illus. 1912.)

(8) MALLERY, T. D.
1941. RUBBER STUDIES BEGIN. U. S. For. Agr. Rel., Agr. Amer. 1 (12) : 5–6, illus.

(9) RANDS, R. D.
1924. SOUTH AMERICAN LEAF DISEASE OF PARA RUBBER. U. S. Dept. Agr. Dept. Bul. 1286, 19 pp., illus.

(10) ———
1942. HEVEA RUBBER CULTURE IN LATIN AMERICA. India Rubber World 106 (3) : 239–243; (4) : 350–356; (5) : 461–465, illus.

(11) SANCHEZ DEL AGUILA, M.
1941. PERU IS ON THE JOB. U. S. For. Agr. Rel., Agr. Amer. 1 (9) : 6–9, illus.

(12) SORENSEN, H. G.
1942. CROWN BUDDING FOR HEALTHY HEVEA. U. S. For. Agr. Rel., Agr. Amer. 2: 191–193, illus.

(13) STAHEL, G.
1917. DE ZUID-AMERIKAANSCHE HEVEA-BLADZIEKTE VEROORZAAKT DOOR MELANOPSAMMOPSIS ULEI, NOV. GEN. (=DOTHIDELLA ULEI P. HENNINGS). Suriname Dept. Landb. Bul. 34, 111 pp., illus.

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